Energy Management Practices: A Study on the Small and Medium Chemical Process Industries from Western Region of India

Synopsis of the PhD Thesis

Submitted by

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CHAPTER 1

ABSTRACT

Climate Change, a consequence of carbon intensive activities has posed some of the harsh and irreversible impacts on the ecosystem. The sustainability of entire human civilization has become a challenge, recognizing this need and to mitigate the impact of climate change, India has made an impressive progress by strengthening the existing initiatives and bringing in new energy reforms.

Many companies are taking part in India's journey for energy sustainability, proactively, using available and affordable measures to optimize their energy need. The research identifies three essential gaps from an exhaustive literature review, viz, a lack of integration of management and technology perspectives, lack of policy intervention and implementation, and failure by organizations to consider energy as a strategic objective at par with productivity. These gaps fueled the need for the study essentially because chemical process industries being energy-intensive, can gain from managing energy effectively. The state wise quantitative data on energy savings from SME sector is not easily available thereby necessitating the development of a framework. Further, the study is focused on determining the existing energy optimization potential in chemical process SMEs. The literature analysis led to development of three research questions related to: factors responsible for putting energy into company's strategic agenda, the company's ability to optimize energy from its current systems and the influencing factors and challenges to adoption of energy management practices for chemical process SMEs.

This exploratory research collected primary data from 60 chemical process SMEs, using a structured and guided questionnaire and personal visits. Based on the theoretical framework, two matrices are designed, viz Energy Management Maturity Matrix and Energy Efficiency Maturity Matrix. The results are statistically analysed to find significant association and correlation.

The score achieved from matrices is used in predicting the existence of energy optimization potential in chemical process SMEs. The analysis of the research can be extended for other chemical process SMEs as well as energy intensive industries other than chemical process industries with some retrospection depending on the industry's operations.

CHAPTER 2

INTRODUCTION

1.1 Introduction

Energy is an important requirement for any organization, particularly so, if the organization is a chemical process industry and almost 5 – 20 % of their cost of production is utility or energy costs (Mahajan and Mokakshi, 2015). Considered as a secondary resource, energy conservation, and optimization find low priority, as the main focus of the organization is production (Schulz *et al.*, (2016)). Sustainable and optimized use of energy is gaining popularity to reduce greenhouse gas emissions, mitigate climate change, and decrease the carbon footprint. Various governments, businesses, and stakeholder's efforts to alleviate climate change aiding environmental preservation are visible by their concern for energy management and energy efficiency.

The global stage was set when 195 countries signed the Conference of Parties 21 also known as COP 21, aiming "to set a goal of limiting global warming to "well below 2^0 Celsius" compared to pre-industrial levels". To reduce emissions of greenhouse gases and lowering of carbon footprint, the United Nations development program (United Nations Development Programme, 2015) has stressed "Climate action" and "affordable and Clean Energy" as part of their seventeen sustainable development goals. These two goals are interdependent. The process of energy generation, using conventional sources, has its imprints seen in the global climate scenario. The goal of COP 21 was reaffirmed by countries in COP 26 as well, with more concern and stressed that human activities have caused around 1.1^0C of global warming to date, results of same are already being felt in every region (United Nations Development Programme, 2021).

On the backdrop of the global efforts, India in COP 26, committed to reduction of total projected carbon emission by one billion tonnes from now to 2030, reducing the carbon intensity of the economy by 45% by 2030, over 2005 levels and achieving the target of net zero emissions by 2070. Accordingly, India's Nationally determined contributions (NDCs) focused on Zero effect, zero defect (ZED) manufacturing to enhance energy and resource efficiency, to reduce pollution and manage waste, and to use renewable energy (Ministry of Micro, Small and Medium Enterprises, 2023). As a step towards the ZED mission, the Indian government has cut subsidies and increased taxes on fossil fuels by almost 26% turning the carbon subsidy regime into one of carbon taxation

(https://unfccc.int/NDCREG). All these factors should contribute as an encouraging factor for Chemical process industries to progress in energy management and conservation. Energy optimization, benefits an organization by reducing its energy usage, decreasing fuel requirements, increasing its revenue and non-revenue benefits, and enhancing its green image. The Covid 19 pandemic and the impacts of the lockdown, has taught us to respect nature, and underscores the imperative to reverse and protect the nature. The impairment that has been done for ages by humans to enjoy a modern and state-of-the-art lifestyle can be reversed by sincere efforts (Parekh et al, 2022).

Energy management and Energy Efficiency are interrelated concepts with Energy efficiency being an integral part of energy management (Chavan and Jain, 2014). Energy efficiency is achieved when energy intensity (energy required per unit of product) in a specific product, process, or area of production or consumption is reduced without affecting output, consumption, or comfort levels as discussed by Backlund et al., (2012) highlights that despite the increasing activity regarding energy management in business practice, there exists a disagreement in the understanding of energy management in academic literature. Parekh et al., (2023) identified three essential gaps in the available sample of the literature: a lack of integration of management and technology perspectives, lack of policy intervention and implementation, and failure by organizations to consider energy as a strategic objective on par with productivity. This research considers Energy Management Practices is culmination of energy management policies and process incorporated by company and energy optimization (efficiency) methods, which considers energy as one of the strategic agenda in business.

Mahajani and Mokakshi (2015) in their book, describes Process industry or Chemical industry as an industry that converts raw materials into processed goods, using different physical or chemical processes which permanently change the properties of the basic materials in order to obtain a desired form, in large quantity. This industry encompasses manufacturing of basic chemical raw materials, fertilizers, pesticides, paints, synthetic chemicals, fine chemicals, specialized chemicals, textiles, petroleum, pharmaceuticals, dyes and pigments, metal, minerals, ceramics, paper, and consumables such as food, beverages, cosmetics and tobacco and others.

Small and Medium Enterprises (SMEs) play a crucial role in achieving the growing demand of products in domestic as well as international markets due to their flexibility of operations, high contribution to domestic production, increasing export earnings, ability to develop and use appropriate technologies as observed by Thiele et al., (2013). In order to compete, SMEs have to

ensure a balance between their turnover, quality, and cost, this leads to their focus on production strategy solely and the issue of energy and resource efficiency are rarely addressed (Sivill et al., (2013)). As per Mittal et al., (2016) and Amrinder, (2016), SMEs are the backbone of the Indian economy, with more than 36.18 million units contributing 9 % of India's GDP, employing 60 million people in India, and 40% export share. SMEs represent the considerable energy-saving potential in the range 5 – 20%. To make SMEs embark their share in energy optimization, the Indian Government is committed through policies, energy efficiency programmes, financial help and incentives. But in spite of government working hard to make energy conservation competitive, the impact is much below desired outcomes (Kumar et al., (2018))

This prompted the research to understand and study the ongoing energy management practices of chemical process SMEs, including the influencing factors for its adoption as well as the challenges faced by this companies. The western region of India, precisely Maharashtra and Gujarat are considered in this research as the two states that are hub of Chemical process industries and have many industrial zones dedicated to SMEs. The states of Gujarat and Maharashtra were also chosen, as they were rated as contenders by the central agency for their energy efficiency index 2019 and need to increase their level to achievers or front runners. The underlying difficulties for SMEs preventing them from enchasing on the opportunity of energy optimization also needs to be studied.

The research aims to identify the factors necessary for incorporating energy management practices in chemical process SMEs to enhance its energy optimization potential.

1.2 Need for the study

- Being energy-intensive, the process industries can gain from managing energy effectively.
- The study will help industries in achieving their Energy management goals (reduced energy consumption, lowering carbon footprint and attaining certifications like ISO 50001)
- Profitable opportunities exist with respect to energy management and energy efficiency.
- State wise quantitative data on energy savings from SME sector is not easily available thereby necessitating the development of a framework.

1.3 Proposed chapter scheme

This synopsis consists of 7 chapters (including the introduction). Chapter 1 consists of the abstract of the study, chapter 2 begins with introduction about the energy scenario on global as well as National level and that for chemical process SMEs, followed by need of the study. Chapter 3 sets the objective for the study. In chapter 4 literature review with gap analysis is presented. Chapter 5 deals with framework of the study, collection of primary data, the design of the matrices, ways to achieve score for the matrices and results and discussion. Chapter 6 gives the summary and conclusion of the energy management practices at chemical process SMEs in western region of India. Finally, chapter 8 presents the limitation and future scope of the study.

CHAPTER 3

OBJECTIVES

The objective of the research is to develop a framework for studying the energy optimization potential of small and medium chemical process industries. The framework will provide guidelines for understanding the variables on which the energy optimization potential of SMEs depends and would help diagnosing the issues faced by them. The framework and matrices design are response to the below mentioned research objectives.

RO_1: To develop a framework to estimate the current energy optimization potential of small and medium chemical process industries.

RO_2: To develop energy management maturity matrix and energy efficiency maturity matrix.

RO_3: To study the issues important to be considered for putting energy on company's strategic agenda.

RO_4: To explore the barriers and drivers for Energy management practices in Indian chemical process SMEs.

RO_5: To identify the ways in which companies are utilising their current energy systems to reach higher efficiencies.

RO_6: To study the possibilities for finding alternative revenues from the company's energy system

CHAPTER 4

LITERATURE REVIEW

4.1 Energy Management concept

Energy sustainability depends on a sustainable energy supply, sustainable energy consumption, and sustainable waste disposal. According to International Energy Agency (2020), sustainable development draws 40% of its future carbon reduction from energy efficiency. Energy has been considered a support function in industry, with no to low priority in terms of conservation since the main focus of industry is to enhance productivity (Schulze et al. 2016). Chemical process industries, being energy intensive in nature, still struggle to strategically and sustainably consider energy management issues. This situation is changing rapidly due to a decreasing availability in crude oil, gas, and coal, rising energy prices, increasing awareness about their environmental effects, and a concern to alleviate climate change. To adapt into this changing situation, energy management can be important focal point, for industries and government, as it can be fast and economical way to save money and lower carbon emissions (Lovins, 2018). Energy management contributes to energy security and can simultaneously create competitive advantage for the organization (Smith et al., 2022).

Kannan & Boie (2003) defines "energy management" as ". . .*the judicial and effective use of energy, to maximize profits and to enrich [the] company's competitive positions, through organizational measures and optimizing energy efficiency in the operations*". Cooremans and Schonenberger's (2019) definition of energy management is "…*the process of organizational, technical or human actions enabling organizations to use energy in more efficient way to reduce energy consumption in profitable way*". Energy management can thus be achieved by combining the skills of engineering (optimizing the use and cost) and management (planning, implementation, control and organizing). Energy management, when executed diligently, leads to reduction in energy demand, lowers operational cost of production, and mitigate adverse environmental and social consequences. This elevates a company's position in the carbon market, bolsters customers' willingness to pay, and shareholders' willingness to invest. To harness available energy resources effectively and to promote the sustainability of industrial systems, industries must optimize energy through energy management and adoption of efficient solutions and tools. According to Parekh et al. (2022), industries have to realize that energy management can be an effective lever for enhancing their production systems and operations toward improved energy efficiency and hence reduce energy use and related energy costs.

Chavan and Jain (2014) proposed that energy management and energy efficiency are separate but interconnected concepts. ISO 50001 or DIN EN 16001 defines Energy efficiency as the ratio between achieved performance or the profits from services, goods or energy, and the energy used to achieve this. Energy efficiency is vital part of energy management and is attained when energy intensity (energy required per unit of product) in a specific product, process, or area of production or consumption is lowered without affecting production output or consumption.

This is true for process industries as they are major consumers of energy (electricity, oil, gas, and coal) and emitters of greenhouse gases and carbon. Several factors must be integrated for successful energy optimization; these are investigated in the academic literature through research into topics such as energy management, energy efficiency, the challenges to and drivers of energy management practices, energy efficient methods, energy conservation techniques, and the development of key performance indicators. This research builds on this previous works of systematically reviewing the literature, as originally outlined by Tranfield et al. (2003) and applied in the area of energy management by Schulze et al. (2016).

4.2 Selection of literature for the study

Considering advances in technology, the period from 2000 to 2022 has been chosen since many articles, reports, and case studies have been published on energy management practices, energy efficiency, energy management systems, energy efficient technologies, energy performance indicators, and energy performance measurement. The focus when selecting articles was on the following: the time and type of publication; the availability of full-text articles; the sectors considered; the type of studies undertaken (case study, survey, and literature review); and the content of articles, including energy management practices and/or energy efficient methods or technology (Parekh et. al., 2019). The selected articles include peer-reviewed journal articles, and white papers and reports by national agencies to account for continuous improvement and technology diffusion by industries or national agencies. The contents of articles vary, from an emphasis on energy-efficient technology, its application, its analysis, the importance of energy management, case studies of success, benefits of energy management, reports on energy scenarios across the world, energy management practices, and articles that describe successful energy management systems and energy indicators.

Based on the aforementioned criteria, 99 articles, including 84 peer reviewed articles and 15 reports, were studied to discover the best practices available across the world, and their application to chemical process industries. There are 44 articles that showcase the energy opportunities in manufacturing sectors, followed by 36 articles on the chemical process sector, including chemical manufacturing, the petroleum, pharmaceutical, iron and steel, and paper and pulp industries, cement manufacturing, and water treatment plants. Table 1A and Table 1B represents list of few articles of importance and their essential focus areas.

Table 1A: Details of few articles, including their focus areas and affinity to demographic location.

Author and year	Title of paper	Journal	Focus	Region
Smith, wt al. (2022)	Barriers and drivers for industrial energy management: The frontine perspective	Journal of Cleaner Production, Elsevier	Barriers and Drivers	Global Perspective
Anupama Prashar (2020)	Eco-efficient production for industrial small and medium-sized enterprises through energy optimization: framework and evaluation	Production Planning and Control, Taylor & Francis	Eco-efficiency indicators for SMEs	India
Alliance for energy efficiency economy, Ministry of power and Bereau of Enerfy Efficiency (2019)	Report on State energy efficiency index - 2019	Alliance for energy efficiency economy	State wise energy efficiency of industries	India
Cooremans and Schönenberger (2019)	Energy management: a key driver of energy-efficiency investment?	Journal of Cleaner Production, Elsevier	energy management and energy efficiency investments - through survey	Switzlerland
Solnørdal and Foss	Closing the Energy Efficiency Gap—A Systematic Review of Empirical Articles on Drivers to Energy Efficiency in Manufacturing Firms	Energies, MDPI	Enerrgy efficiency - Lit review	Global Perspective
Naik and Mallur (2018)	The benefits of Energy Efficiency in Small and Medium Enterprises	Material science and Engineering, IOP Publishing	MSMEs	India
Amarinder (2016)	A Study of Small and Medium Enterprises (SME) in India on Sustainability Strategy : Highlighting Critical Challenges and Constraints	Journal of Asia Entrepreneurship and Sustainability, RossiSmith Academic Publications	SMEs and Barriers	India
Trianni, et al. (2016)	Barriers, drivers and decision-making process for industrial energy efficiency: A broad study among manufacturing small and medium-sized enterprises	Applied Energy, Elsevier	Barriers and Drivers	Italy
Schulze, et al. (2016)	Energy management in industry: a systematic review of previous findings and an integrative conceptual framework	Journal of Cleaner Production, Elsevier	Energy Management - Literature review	Global Perspective
Brunke, et al. (2014)	Empirical investigation of barriers and drivers to the adoption of energy conservation measures, energy management practices and energy services in the Swedish iron and steel industry	Journal of Cleaner Production, Elsevier	Barriers and Drivers to ECM, EMP	Sweden
Cagno and Trianni (2013)	Exploring drivers for energy efficiency within small- and medium-sized enterprises: First evidences from Italian manufacturing enterprises	Applied Energy, Elsevier	Drivers for SMEs	Italy

Table 1B: Details of few articles, including their focus areas and affinity to demographic location

Author and year	Title of paper	Journal	Focus	Region
Rudberg, et al. (2013)	Strategic perspectives on energy management: A case study in the process industry	Applied Energy, Elsevier	Energy Management as strategic agenda	Sweden
Trianni, et al. (2013)	Barriers to industrial energy efficiency in foundries: a European comparison	Journal of Cleaner Production, Elsevier	Barriers	Europe
Saidur, et al (32011)	A review on energy saving strategies in industrial sector	Renewable and Sustainable Energy Reviews, Elsevier	Energy conservation strategies - review	Global Perspective
Madloola, et al. (2011)	A critical review on energy use and savings in the cement industries	Renewable and Sustainable Energy Reviews, Elsevier	SMEs	China
Gordic, et al. (2010)	Development of energy management system - Case study of Serbian car manufacturer	Energy conservation and Management, Elsevier	Energy Management	Serbia
Thollander and Ottosson (2010)	Energy management practices in Swedish energy-intensive industries	Journal of Cleaner Production, Elsevier	Energy management practices	Sweden
Worrell, et al. (2009)	Industrial energy efficiency and climate change mitigation			Global Perspective
Thollander et al, (2005	Reducing industrial energy costs through energy efficiency measures in a liberalized European electricity market	Applied Energy, Elsevier	Energy efficiency measure and associated costs.	Europe
Joachim Schleich (2004)	Do energy audits help reduce barriers to energy efficiency? An empirical analysis for Germany	International Journal of Energy technology and Policy	Barriers	Germany

Increase in economic growth, development, population and trade has played major share in increased carbon emission impacting the environment in all possible ways. Studies focusing on reducing energy related CO2 emissions with aid of energy efficient solutions and renewable energy is increasing. (Hailemariam, A., & Erdiaw-Kwasie, 2022).

4.3 Classification of Literature:

Many articles are published on energy management practices, but they are fragmented in terms of concepts, industry, country, and policies. Learning from these will help cultivate further research, developments, and innovation unique to relevant sectors, industry types, and countries. This research analyses and categorizes the literature on three major categories: management, technology, and influencing factors as in Fig 1. The articles analyzed were broadly categorized by their focus of study, highlighting the perspectives of energy management, technology, influencing factors, and SMEs. This categorization helps in understanding importance of each category in detail and an additive impact it can create if used in combination with through study.

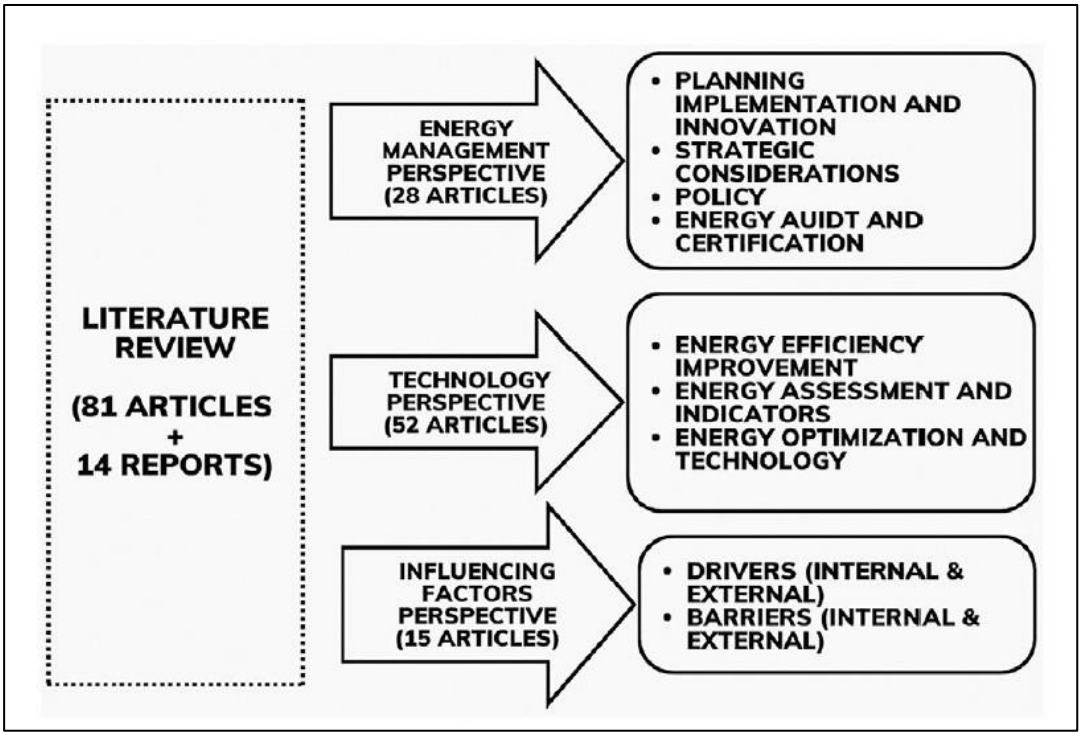
LITERATURE REVIEW
(81 ARTICLES + 14 REPORTS)
ENERGY MANAGEMENT PERSPECTIVE (28 ARTICLES)
• PLANNING IMPLEMENTATION AND INNOVATION
• STRATEGIC CONSIDERATIONS
• POLICY
• ENERGY AUIDT AND CERTIFICATION
TECHNOLOGY PERSPECTIVE (52 ARTICLES)
• ENERGY EFFICIENCY IMPROVEMENT
• ENERGY ASSESSMENT AND INDICATORS
• ENERGY OPTIMIZATION AND TECHNOLOGY
INFLUENCING FACTORS PERSPECTIVE (15 ARTICLES)
• DRIVERS (INTERNAL & EXTERNAL)
• BARRIERS (INTERNAL & EXTERNAL)

Fig 1: Categorization of literature

Energy Management Perspective

According to Sivill et al. (2013) and Mulder and Hagens (2008), energy management is below raw materials optimization and production commitment as a priority in energy-intensive industries. Thollander and Otterson (2010) suggest senior management be involved in developing their company's energy policy, in managing energy-saving projects, and in creating an environment that thus motivates and trains their employees. Schulze et. al. (2016) demonstrated a comprehensive framework for incorporating **strategic planning, implementation, control** of energy use, reorganizing the **organization structure**, and modifying an **organization's culture** to effectively tap its energy efficiency potential. Gopalakrishnan et al. (2014) also suggested a framework of energy management to effectively implement ISO 50001 to reduce the energy costs and losses from minimizing greenhouse gas emissions. Some 21 articles investigated planning, implementation, and innovation through qualitative and quantitative studies, or a combination of both. Three studies elaborated the process, requirements, and benefits of **energy audits and certifications**. As illustrated in Figure 2, only three studies investigated the importance of using energy management as a strategic objective; just one article examined the impact of policies on energy management. Planning and implementation are core to energy management and require a gradual and structured approach that

starts from the unit process to the factory facility and multi-facility units, incorporating entire supply chain in the process if possible (Duflou et al. 2012). Alternately, Sivill et al. (2013) focused on incorporating proper **change management** tools and rewards to make energy management successful. There are many ways to effectively implement energy management in an organization which may differ based on geographic locations, sectors, or the scale of operations. Backlund et al. (2012), using the multiple case study model for Sweden, found energy-intensive firms to be more enthusiastic and successful in adopting energy management.

Technology Perspective

Energy efficiency can be achieved through the appropriate use of technological interventions and processes by upgrading existing systems or replacing existing systems to achieve energy-efficient systems, depending on the situation. Lipiäinen et al. (2022) suggest use of bio-alternatives to replace fossil fuels, thus decreasing the carbon intensity of processes. Exothermic processes release energy into the environment; this can be efficiently trapped for useful energy on-site. Pinch technology and heat exchanger networks to **integrate process streams** are used frequently. Geldermann et al. (2006) took the automobile industry as a case study to demonstrate that blending process integration engineering with operations research can provide economic and environmentally friendly solutions. Waste heat recovery is a big challenge for process industries as it entirely depends on amount, quality, and source of waste heat. Many studies exploit this challenging area of design for recovering low-grade waste heat in the process industry; Law et al. (2016) demonstrated this through a case study, using knowledge-based programs and available plant data. The case study of Oluleye et al. (2016) also investigates different models of on-site waste heat utilization by recording the temperature and duties at the heat source. In a literature review, Chan et al. (2013) illustrated the possibility of recovering low-grade heat using technologies like “Chemical heat pumps, organic Rankine cycles, [and] thermal energy storage”. Ammar et al. (2012) evaluated the technical and economic feasibility of extracting low grade thermal energy using CFD (computational fluid dynamics) for process industries in the United Kingdom, provided that strong government regulations and policies are in place; similar approaches may be applied in other countries.

Even some economical **modifications to existing equipment** or replacing the energy-intensive with energy-efficient parts can help reduce the energy requirement of the plant. Enhancing awareness and

identifying action areas to improve the energy use of processes can be effective if **energy analysis** is conducted at manufacturing level (Andrei et al.,2022). Saidur et al. (2010) reviewed and further identified energy saving techniques—such as variable speed drives, energy efficient motors, recovery of waste heat, leakage avoidance, and pressure drop reduction—for energy-intensive motor-driven process industry equipment. The speed and scale at which technology develops and diffuses across industries, the cost of technology, energy prices, the intensity of chemical industrial activities, and national and international policies will determine the potential effects of mitigation on climate change (Worrell et al., 2009). Xuezhi et al. (2011) emphasized the need for energy saving as a low-cost option with a high potential to benefit the present scenario. Outsourcing energy optimization activities to energy service companies (ESCOs), with the latest know-how required for energy efficiency, and funds to operationalize it, is seen as the latest trend by Benedetti et al. (2015).

According to Lindberg et al. (2015), **key performance indicators**, used for monitoring operations in industries, need to be benchmarked to similar processes or equipment to classify areas of improvement and necessary actions to be developed and implemented to bridge gaps. Worrell et al. (2003) illustrated the importance of incorporating the productivity benefits associated with energy efficient technologies in terms of cost savings related to conserved energy.

Influencing Factors Perspective

Drivers to energy management, as defined by Cagno and Trianni (2013) are "factors facilitating the adoption of both energy-efficient technologies and practices, thus going beyond the view of investments and including the promotion of an energy-efficient culture and awareness." Stringent environment requirement, government regulations, incentives and awareness drive iron and steel industries in Sweden towards adopting energy management, as per the study by Brunke et al., (2014). Trianni et al., (2016) and Singh et al., (2008) lists organization's policy, long term strategy, top management commitment and realization of low energy benefits as positive influencers for SMEs in manufacturing industry. Rudberg et al., (2013) describes recognition of non-energy benefits for process industries.

Sorrell et al., (2011), defines **barrier** to energy efficiency as a hypothesised mechanism that deters an energy efficient and cost effective decision or behaviour. The theme of their studies also suggests that barriers to energy efficiency are multidimensional, varied and diverse and specific to the industry

type and technologies used therein. Smith et al., (2022) and Lee KH (2015), in their study emphasises the fact that understanding the barriers and drivers, to energy conservation and optimization, from frontline workers is also important. As per the study by Singh et al., (2008) for Indian SMEs, the challenge lies in cost, quality, deliverables and human resources development for survival. Minciuc et al., (2017) in their study considers limited access to capital and knowledge of energy efficient technologies alongside lack of awareness amongst employees and top management as essential barriers for energy conservation and optimization.

The factors within the organization that prevents the shift towards energy efficient management, could be contributed as **internal factors**. Various myths contributed as negative influencers, as discussed by author Ammar et al., (2012) and Thollander and Ottosson (2010) in their papers, regarding perception that energy efficient technologies have higher investments and would have negative impact on the production activities. Factors outside the organization control (**external factors**), also hinders the effective energy management within organization like, support from financial institutions for promoting energy efficient technologies, as suggested by Worrell et al., (2009), absence of incentives, limited availability of public information and lower energy price as noted by Bhattacharya (2010) and Alcorta et al., (2014) in their studies for developing countries. It is imperative to work to weaken the barriers and strengthen the drivers for successful implementation of energy management and to mitigate the climate change. Parekh et al., (2022) categorized drivers and barriers to energy optimization in Indian context, using literature and preliminary survey, into internal and external factors and further analysed them using PESTEL analysis for external factors and SWOT analysis for internal factors. The conclusion from the analysis is the emphasis on importance of evaluating the internal and external factors based on situation and industry type for designing the energy optimum solution. Figure 2A and 2B displays the external positive (Drivers) and negative (barriers) influencing factors.

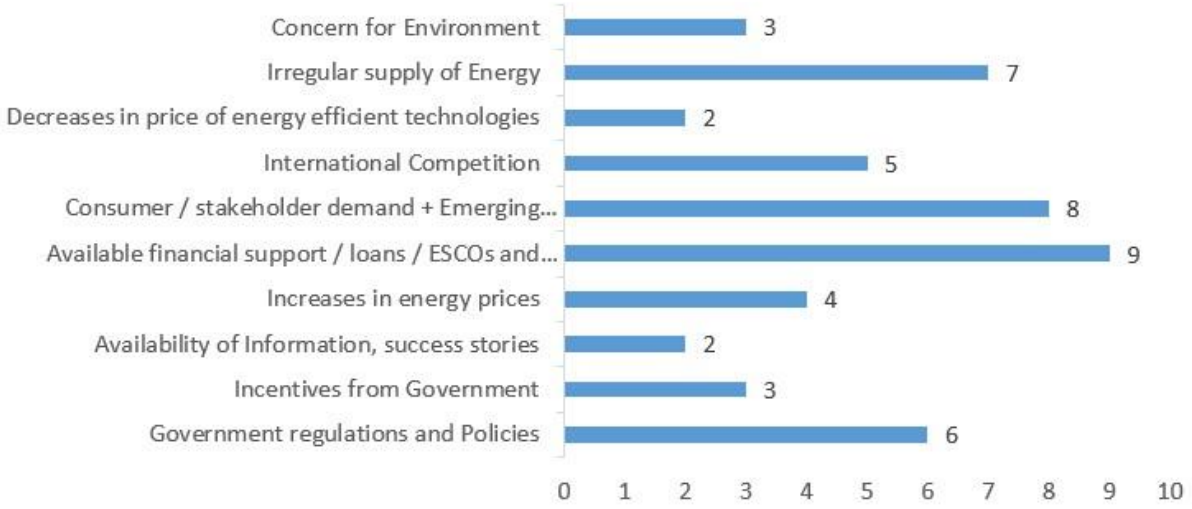

Fig 2A: External Drivers

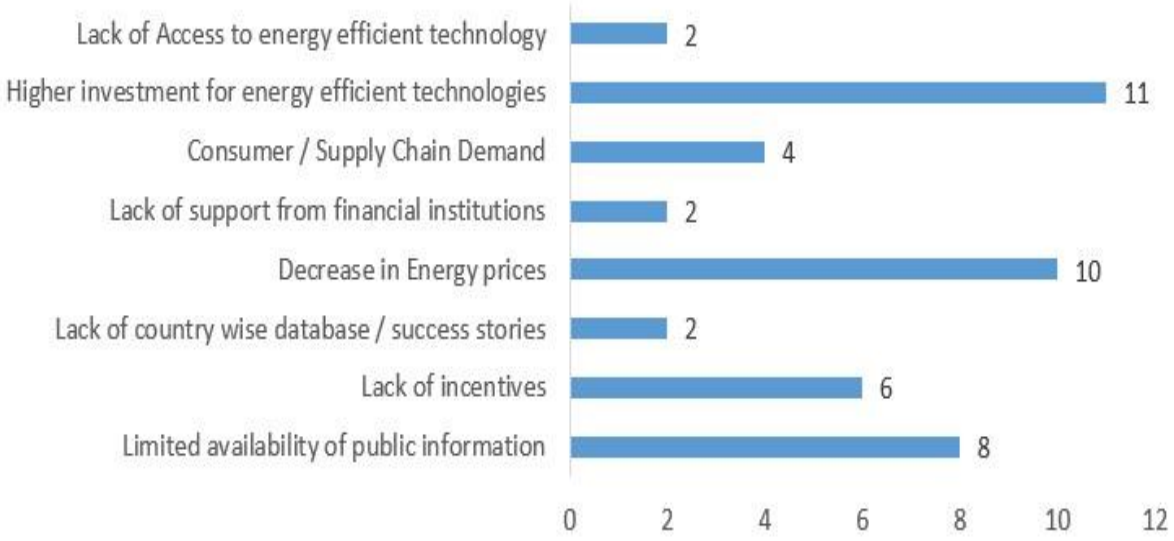

Fig 2B: External Barriers

Financial support for adoption of energy efficient technologies is considered to be top driver followed by Stakeholder demand and emerging market opportunities from literature review. Perception of high investment in energy efficient technologies and decrease in energy prices (scenario before 2021) were top rated challenges crippling the energy efficiency as per literature.

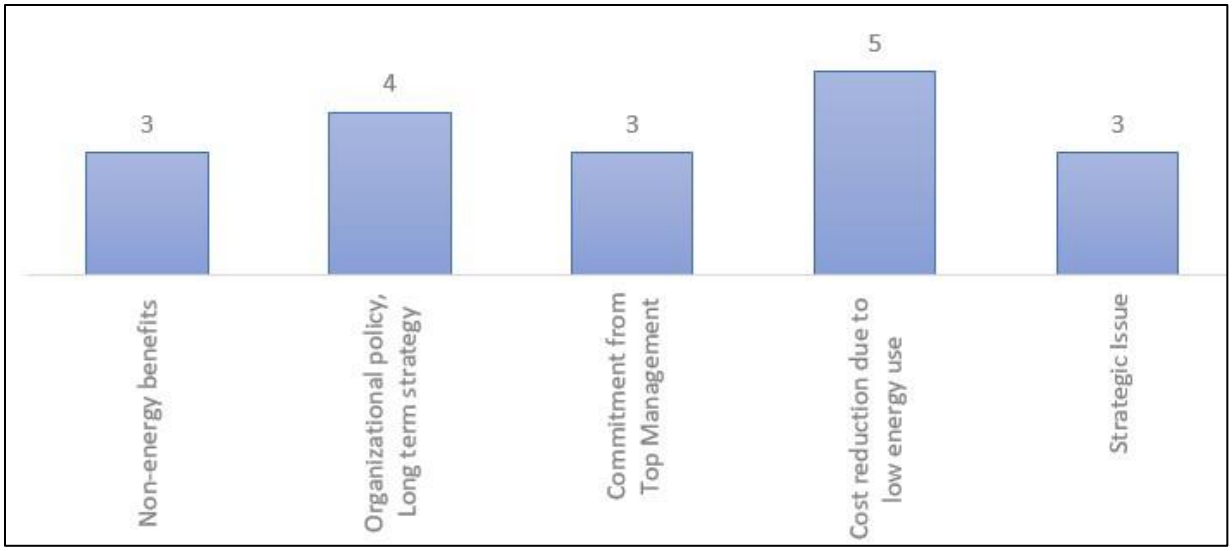

Fig 3A: Internal Drivers

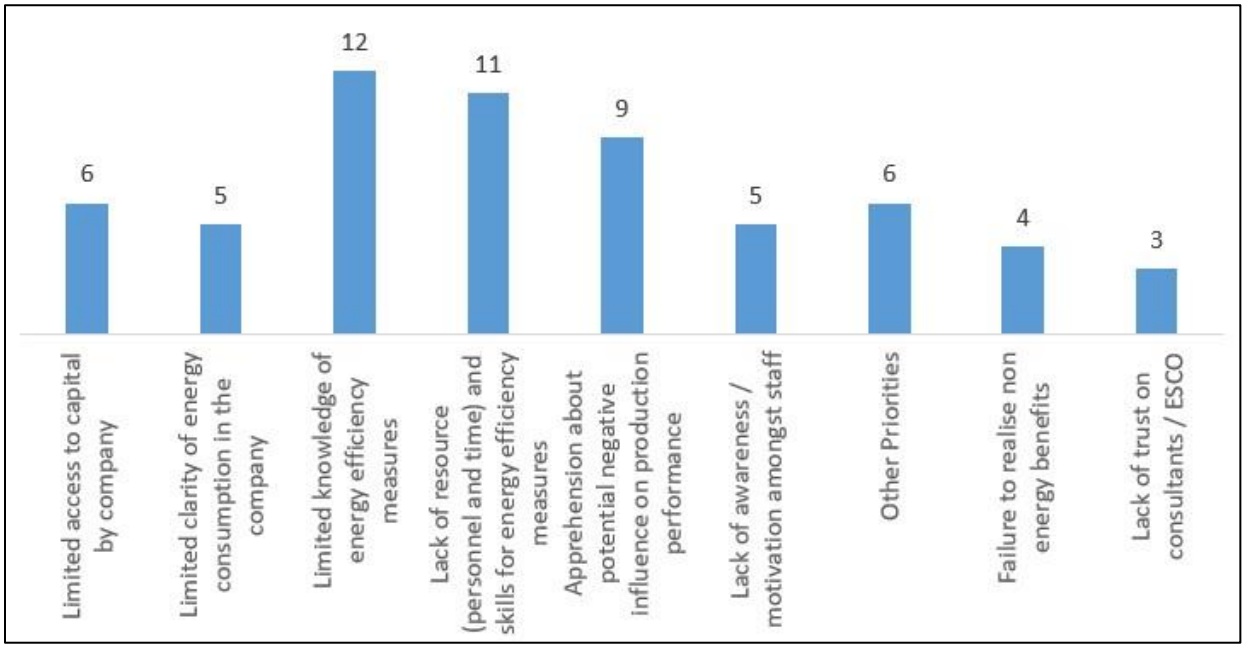

Fig 3B: Internal Barriers

Figure 3A and 3B represents Internal Drivers and Barriers to energy management practices which are in control of the organization. The realization of cost reduction and top management support by policies and strategies is being rated high positive influencers whereas limited knowledge of energy efficiency measures, lack of resources and perception of negative influence on production are the top challenges organizations faced as per the literature.

4.4 Research Gaps as identified from Literature

The advancement in technology, cross country exchange of technology, sustainable business, multinational business, competition, and change in the political scenario, have raised the need to re-exploit the challenges and drivers. However, compared to studies and research in developed countries, the Indian scenario remains less explored for the effective implementation of energy management practices. The scenario is changing rapidly for large scale industrial sectors (SEI 2020) but for SMEs it is still a challenge. The detailed review and analysis of the literature, led to following research gaps specially for India:

- Research concerning actual energy management practices in industries are scarce. The concept of energy Management and energy efficient methods are studied and applied in **isolation**.
- Energy management and Energy efficiency are considered only during redesigning of plant or when new investments have to be made, but **continuous monitoring** is still missing by the industrial conduct, especially SMEs.
- Some chemical process industries that have the possibility to extract an energy surplus as by-product, can work as **alternative source** of generating revenue, this realization is scarce in SMEs and it leads to energy wastage or loss.
- Ambiguity in collection of primary data for SMEs due to **lack of monitoring or measurement** of energy usage.
- **Benchmarking** and analytical studies for energy efficiency in Indian SMEs is yet to be undertaken by energy agencies or GOI
- Energy management and energy-related issues have previously been in focus for many research projects in process industries, e.g. the pulp and paper industry, the combined heat and power industries, the district heating industries and, as in this study, the chemical industry. Yet, very few of these studies treat energy management from a **strategic management perspective** to identify the necessary prerequisites for putting energy management on the companies' strategic agenda.
- There is scarcity of **published procedures and methodologies** to guide a company through energy management practices.

CHAPTER 5

CONTRIBUTION

5.1 Development of Framework:

Gordic et al., (2010) and Schulze et al., (2016) developed the framework for energy management system and integrated energy management respectively. Its validity was tested from manufacturing sector's early adopters in the country of Serbia and Sweden respectively. The framework delved into layers of energy management requirements. The present study is extending these frameworks, with addition of new variables based on the considerations from the exhaustive literature review and subsequent gap analysis, for the Indian scenario. This emerging field of energy management practices has driven the researcher to formulate the framework to study and assess the **energy optimization potential (tapped and untapped) of S&M chemical process industries (EOP).** As mentioned in section 4.2, the energy management practices are categorized in three categories, energy management perspective, energy efficiency perspective and influencing factors perspective. The influencing factors were studied in detail and variable like realization of benefits of energy optimization was considered to be studied in detail and added to framework. The proposed framework is shown in figure 4. The review of energy management literature reveals that there is lack of a comprehensive evaluation of energy optimization potential based on the current energy management practices of the companies across the industries globally. Indian scenario is no different specially for chemical process SMEs. This framework give comprehensive integrated approach using the management and technology perspective along with understanding of influencing factors perspective, rather than focusing on them individually.

The dependent variable in the framework is 'Energy optimizing potential (tapped and untapped) of chemical process SMEs (EOP), whereas the three independent variables include, 'current energy management policies and practices (CEMPP)', 'current energy efficient methods adopted (CEEMA)', and 'the realization of benefits (RB)' as illustrated in Fig 4. The framework also aided in understanding of influencing factors (motivators or drivers) and challenges (barriers) and the central and state policies to energy management and optimization as perceived by the SMEs.

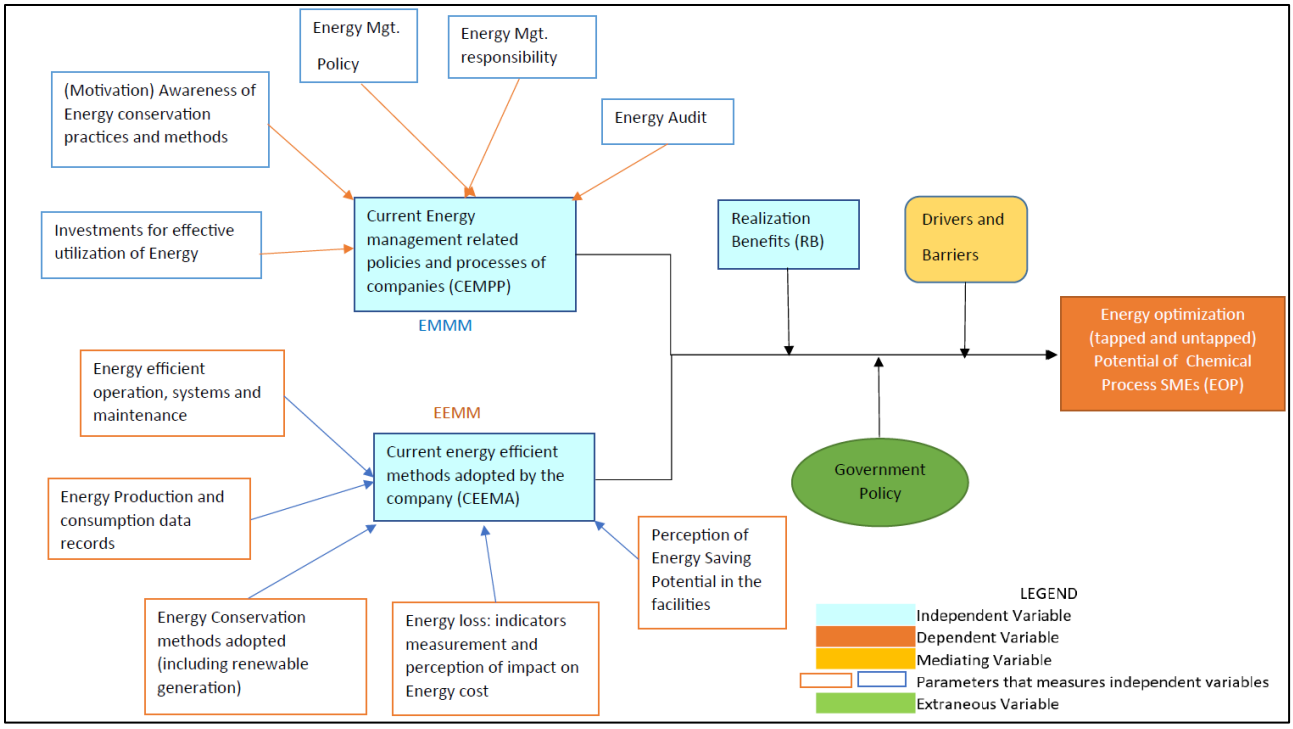
Energy Mgt. Policy
Energy Mgt. responsibility
(Motivation) Awareness of Energy conservation practices and methods
Energy Audit
Investments for effective utilization of Energy
Current Energy management related policies and processes of companies (CEMPP)
EMMM
Realization Benefits (RB)
Drivers and Barriers
Energy optimization (tapped and untapped) Potential of Chemical Process SMEs (EOP)
Energy efficient operation, systems and maintenance
EEMM
Current energy efficient methods adopted by the company (CEEMA)
Government Policy
Energy Production and consumption data records
Perception of Energy Saving Potential in the facilities
Energy Conservation methods adopted (including renewable generation)
Energy loss: indicators measurement and perception of impact on Energy cost
LEGEND
Independent Variable
Dependent Variable
Mediating Variable
Parameters that measures independent variables
Extraneous Variable

Fig 4: Framework to analyze Energy optimization potential of chemical process SMEs.

5.1.1 Energy Optimization potential (EOP)

The dependent variable energy optimization potential (tapped and untapped) of chemical process SMEs, is measure to identify how chemical process SMEs are utilizing their energy systems in line with the commitment by government of India, to reduce carbon emission. The potential for energy optimization do exists, specially in chemical process industries as they consume considerable amount of energy to produce various life essential products. Some chemical process companies also generate energy due to their exothermic processes of production, which if successfully entrapped can reduce the energy bills of the companies. Irrespective of whether a company generates its own energy, energy consumption can be optimized through a spectrum of measures, spanning from low cost and no cost strategies to more substantial investments. These measures encompass practices such as diligent housekeeping, regular maintenance, adoption of state of the art production technologies, and maintaining comprehensive records of energy utilization, generation and losses throughout processes and transition. The understanding of EOP, whether tapped to certain extent by some companies or

untapped yet, will help in developing measures to realize this opportunity and help government (state as well as central) to develop further policies and schemes.

5.1.2 Current energy management policies and practices (CEMPP)

"Energy management" is planned, monitored, controlled, and executed actions to ensure maximum energy output using minimum energy resources for a predetermined performance by an organization to gain competitive advantage, serve national interests, and adhere to stringent environment standards. Energy management is thus the strategic approach of a company toward its energy usage (Parekh, et al., 2022). The academic literature indicates that energy-intensive organizations that adopt a strategic approach to energy management may reduce energy usage as much as 40%. Cooremans and Schönenberger (2019) confirm this and argue that considering energy in strategic planning, implementation, and the control, organization, and culture of an organization can exploit a company's energy efficiency potential. Without long-term strategy and the allocation of energy costs, companies will not realize the benefits of energy management.

CEMPP can be found with the answers to following questions 1) Are the organization's policies and processes related to energy conservation is in place, 2) whether the company goes for energy audit, if so how frequently and how much feedback do they incorporate, 3) does the company have energy manager or any else handling responsibility for energy optimization? 4) how much is the awareness and motivation for energy conservation and optimum utilization amongst the employees and 5) does the company have separate budget for energy related investments or do they even invest in energy conservation methods.

5.1.3 Current energy efficient methods adopted (CEEMA) by SMEs

Energy optimization can be achieved through the appropriate channeling of technological interventions and processes by upgrading existing systems or replacing existing systems to achieve energy-efficient systems, depending on the situation. The chemical process industry naturally lends itself to energy optimization due to its ability to both consume and generate energy through various means, as well as the potential for integrating available energy to enhance efficiency or reduce consumption. CEEMA can be achieved by considering following factors: 1) Availability of

comprehensive energy records and data, 2) The technology used in the production process, the age of equipment / machines, and frequency of maintenance, 3) The energy conservation measures tapped by the company and their effectiveness, 4) Energy loss measurement and perception of loss occurring in facility and 5) perception of energy saving potential in the facility. The last two are perception based, i.e. subjective and can be realized only if the management is aware and interested in energy optimization.

5.1.4 Realization of benefits (RB)

Comprehension of revenue and non – revenue benefits is essential for encouraging the companies to proceed with energy efficiency. The energy efficient measures that the companies take be it low cost measures like use of LED lights to high investment opportunities, the data of revenue saved, tax benefits achieved, lowering of bills, must be maintained, this motivates for moving towards next goal. The non – revenue benefits like contribution towards reduction of carbon footprint, fulfillment of social responsibility towards environment and climate protection definitely encourages more efforts towards energy conservation and optimization. The study of this variable will aid as motivational force towards energy management practices.

5.1.5 Influencing Factors (Drivers and Barriers)

Drivers are considered influencing parameter that enhances positive shift to energy management behavior and barriers are challenges that negatively influence companies away from energy management and optimization practices. The study of the same will help developing mechanisms for the companies as well as stakeholders ensure conducive environment. The perception of the SMEs towards the motivational factors and challenging factors differs based on their location, their state government policies, their financial stability, market opportunities for their products, their strategic agenda, the availability of energy and the scale of operation.

5.1.6 Government Policies

Government policies are external to company's hold, but they influence how companies take advantage of opportunities provided by government through policies. The state energy efficiency index 2018, mentions, the state of Maharashtra and Gujarat has not mandated energy audit, but the same has been mandated in 2020 (SEI 2020). This change in policy encourages companies to at least

go for energy audit, to achieve firsthand information about how they can conserve energy. When energy audit is not a mandate, the companies avoid it, and many times remain unaware about the extra spending or cost, which could be saved, they incur for producing goods. The government policy on conducting operations during non-peak hours, incentives on maintaining 90% power factor for electric utility, tax benefits for generating renewable energy etc, favors energy optimization and management. The diffusion or awareness about these policies for SMEs is yet to be analyzed.

5.1.7 Hypothesis

Based on the framework developed, following **hypothesis** were formulated and tested based on the primary data

H_{01}: There is no significant association between Current energy management policies and processes of chemical process SMEs and Energy optimizing potential (tapped and untapped) of chemical process SMEs

H_1: There is significant association between Current energy management policies and processes of chemical process SMEs and Energy optimizing potential (tapped and untapped) of chemical process SMEs

H_{02}: There is no significant association between Current energy efficient methods adopted by chemical process SMEs and Energy optimizing potential (tapped and untapped) of chemical process SMEs

H_2: There is significant association between Current energy efficient methods adopted by chemical process SMEs and Energy optimizing potential (tapped and untapped) of chemical process SMEs

H_{03}: There is no significant association between Revenue generation or non-revenue benefits resulting due to energy conservation approaches by chemical process SMEs and Energy optimizing potential (tapped and untapped) of chemical process SMEs

H_3: There is significant association between Revenue generation or non-revenue benefits resulting due to energy conservation approaches by chemical process SMEs and Energy optimizing potential (tapped and untapped) of chemical process SMEs

5.2 Methodology for obtaining primary data:

Analyzing the literature for similar constructs and also based on the discussion with the experts in the field of energy management and energy efficiency, a questionnaire, relevant to the developed framework, was prepared and administered to the executives of chemical process SMEs. The questionnaire was finalized after taking inputs for subject experts (Novakowski and Wellar, 2008). The pilot study was undertaken to understand the validity and reliability of questionnaire on set of seven companies and the data was studied using differential analysis. The questionnaire was later modified slightly to get more depth into measurement of variables.

The data collected in this study is primary data gathered from an extensive survey relating to energy management practices of chemical process SMEs from the state of Gujarat and Maharashtra representing the western region of India, a region densely populated by the Chemical process industries. The period of data collection is from 2019 till 2023, period got extended due to Covid 19 pandemic. The state of Gujarat and Maharashtra are considered to be the most industrialized state in terms of chemical process industries. The industrial development zones like Dombivali, Lote Parshuram, Chiplun, Pune, Boiser, Turbhe and Nashik from Maharashtra and Vatva, Ankleshwar, Vapi, from Gujarat were approached. The Secondary sources of data used included information regarding the firms and policies collected from the government reports. Simple random sampling method is used for collecting the samples from the industrial regions of the two states. 150 companies were contacted through telephone to finalize their availability and their acceptance to participate in the survey. Total of 84 companies participated, but the responses of 60 companies could only be considered after data cleaning. The response was collected using the short, guided questionnaire followed by a discussion that gave a detailed understanding of the firm during the plant visit. The information collected during the survey was:

- General data about the company, energy requirement, and operation types (Batch, semi Continuous and Continuous).
- The current energy management practices and policies followed by the company to know how the company is realizing importance of energy management principals
- The current energy efficient methods adopted by the company to understand their energy systems and maintains records and realize the benefits of energy efficient methods.

- The practical and perceived drivers and barriers to energy efficiency and energy management practices.
- The awareness about the government policies and schemes.

5.3 Matrix Development

The two novel matrices were developed to serve as measuring tool for the two independent variables, CEMPP and CEEMA, in the study and when used by an individual company, the matrices serves to identify the current position and maturity level of the company and guides them to ascent to higher levels. The Energy Management Maturity Matrix (EMMM) illustrate in Figure 5 and Energy Efficiency Maturity Matrix (EEMM) in Figure 6 offers a useful insight to learn about a company's current ways of dealing with energy-related matters. The matrices grid displays the state of an organization's energy management and energy efficiency efforts at the moment. It highlights the areas that need additional focus to ensure that energy management and energy efficiency is developed in an efficient manner. Each row from bottom to top, represents the increasing complexity of the issues discussed in columns from 1 to 4.

The EMMM is used to measure the independent variable 1 (CEMPP). Each column of this matrix deals with essential energy management topics: Energy management policy and processes (EMPP), Energy Audit (EA), Energy management responsibility (EMR), Energy related awareness and motivation (AM) and Energy related investments (EI).

The EEMM is used to measure independent variable 2 (CEEMA), and each column in this matrix addresses the energy efficiency related matters: Energy monitoring and records (EMR), Process type, operations and maintenance (TOM), Energy loss measurement indicators and perception (EL), energy conservation methods adopted (ECM) and Energy saving potential perception(ESPP). The independent variable Revenue and non-revenue benefits (RNRB) is measured directly from the scores of the mapped questions.

Criteria	Energy Management Policy and Processes (EMPP)	Energy Audit (EA)	Energy Management Responsibility (EMR)	Awareness and Motivation (AM)	Investments for Energy Optimization (EI)
Level 4	• EM fully integrated in corporate strategy with well written energy policy, • EMS in place that sets targets, monitors and records consumption, identifies deviations and issues and quantifies savings.	• Detailed Audit. • Feedback of EA incorporated from 50 - 100%	• Full Time EM	• Created using training programs, awareness programs, presentations for management as well as staff. • May be carried out by industrial associations, energy experts, Energy auditors, government forums.	• Separate budget for energy optimization and conservation
Level 3	• Informal EM Policy set by some senior manager, • Manual target setting, consumption monitoring, issues identification and savings quantification.	• Targeted Audit • Feedback of EA incorporated from 20 - 50%	• Senior Department Manager / Proprietor	• Creating awareness by organizing programs, trainings and publicizing value of energy conservation and optimization for Staff. • May use service of ESCOs or private consultants/energy auditors	• Investment for appraisal of equipments and refurbish opportunities.
Level 2	• Unwritten guidelines and rules followed by company, • Manually setting targets, monitoring consumption and accounting costs.	• Preliminary Audit • Feedback from EA incorporated from 0 - 50 %	• Process or Project Engineer	• Informal contacts used to promote or achieve energy efficiency. • May use skills of senior company professionals or energy auditor.	• Low cost measures
Level 1	• No policy or guidelines in place, • Bills accounted.	• No energy audit	• None	• Lack of awareness amongst staff and management	• Currently no investments for energy optimization

Fig 5: Energy Management Maturity Matrix (EMMM)

Criteria	Energy Records and Data (ERD)	Process, age and Maintenance (PAM)	Energy loss: indicators measurement and perception (ELMIP)	Energy Conservation methods adopted (including renewable generation) (ECM)	Perception of Energy Saving Potential in the facilities (ESP)
Level 4	• Detailed records of quantity of energy generated (including energy generated by conservation methods), purchased, consumed and lost. • Associated costs and savings.	• Use of energy efficient new process • Equipment age of 0 - 5 yrs. • Regular maintenance.	• PF>0.99, Stack gas temperature < 150, and Air ratio to boiler < 8 - 10%, • Energy losses impact are minimal.	• All possible conservations methods that increases energy optimization and reduces energy consumption and costs, • Renewable energy generated /used as much as possible.	• Facilities have high potential for energy optimization.
Level 3	• Records of quantity of energy generated, purchased and consumed along with associated costs, tracked using energy distribution datasheet, M&EB and loss calculations.	• Use of old process with new plant or equipments • Equipment age of 0 - 10 yrs. • Regular maintenance.	• 0.95<PF<0.99, Stack gas temperature and Air ratio to boiler measured, • Energy loss impact is moderate.	• Energy conservation methods with low payback time adopted, • Renewable energy used.	• Facilities have moderate potential for energy optimization.
Level 2	• Records of quantity of energy generated, purchased and associated costs tracked using M&EB.	• Use of old process with retrofitting or upgradation. • Equipment age of 0 - 15 yrs. and • Annual maintenance.	• 0.9< PF <0.95, • Energy loss impact is considerable.	• Low cost measures adopted • Renewable energy not used or generated.	• Facilities have low potential for energy optimization.
Level 1	• Records of quantity of energy purchased and cost associated with it	• Use of old process / technology • Equipment age more than 20 yrs. • Maintenance > a year.	• No Measurements of important energy loss indicators • Energy loss has very high impact.	• Energy conservations methods not adopted or are unaware. • Renewable energy not used or generated.	• Facilities have no potential for energy optimization.

Fig 6: Energy Efficiency Maturity Matrix (EEMM)

Data measurement and coding for matrices: For EMMM and EEMM

- The questions from the questionnaire were mapped with the different sections of the matrix, measure in range of 1 to 4, as per the level in the matrix.
- Each column score is average of the questions it is mapped with.
- The final matrix score is the summation of each column score, with min score of 5 and Max score of 20.
- The resulting score is considered as value of the Independent variable (construct) under consideration and is divided into quartiles.
- The quartile ranges of 5 to 8.75, 8.76 to 12.5, 12.51 to 16.25 and 16.26 to 20.
- The dependent variable (Energy optimizing potential of SMEs) is measure as ordinal data of Highest Potential (1), High Potential (2), moderate potential (3) and low potential (4).
- The data having both matrix score in last quartile i.e. in range of 16.26 to 20 has very little potential of optimizing energy whereas the data with matrix score below 16.25 has substantial potential for energy optimization

The tilt or inclination was measured using Formula:

- Inclination = EMMM score – EEMM score
- If the difference is positive: The company puts energy on management agenda (Tilt towards effective management practices)
- If the difference is negative: The company considers and acts for energy conservation but the focus on energy as strategic agenda is low. (Energy conservation tilt)

Realization of benefits analysis:

The data from questionnaire is coded in range of 1 and 2, where 1 indicates the non-realization of benefits and 2 indicates realization of benefits.

Influencing factors and challenges analysis:

A five point likert scaling technique was used to grade the responses, where is 1 – low impact, and 5 highest impact. Usage of 5 – point likert scale has been supported by number of researchers such as (Joshi, et al. (2015)) (Jebb, et al. (2021))

5.4 Results and Discussion

5.4.1 General information related to respondents:

The respondent for the research, were randomly contacted from two states of western India, Gujarat and Maharashtra. Figure 7, represents the demographic representation of the respondents. The profile of the respondents varies from manufacturers of surfactant, dyes and pigments, Cement, commercial chemicals, pharmaceutical API, bulk pharma drug, salts, agrochemicals, pesticides, fertilizers, distillation units, textile chemical, derivatives and intermediates, food, specialty chemicals, flavoring agents, paper and pulp, waste treatment industries, poultry additives and intermediates. Of the 60 respondents 32 are from Gujarat and 28 from Maharashtra.

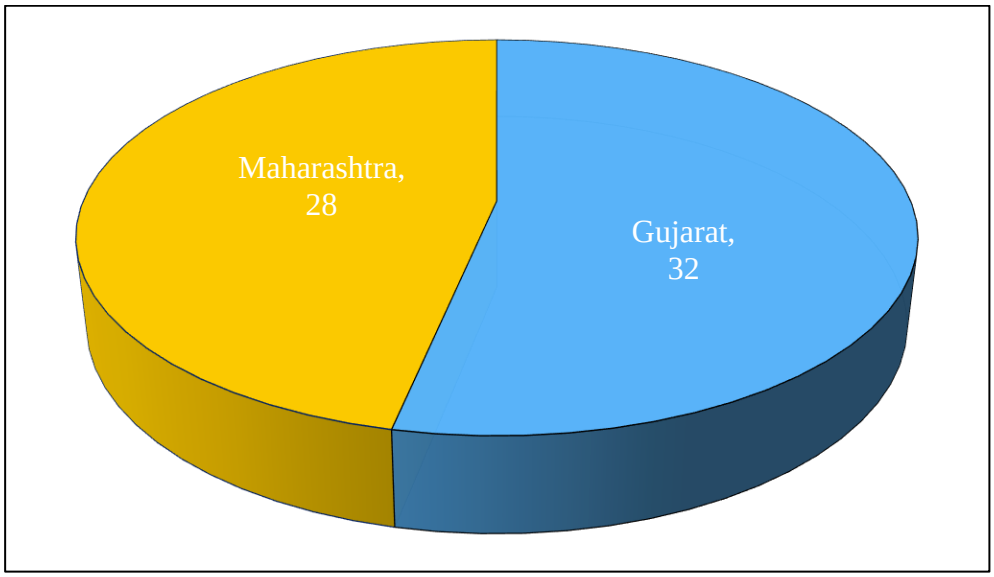

Fig 7: Demographic profile of respondents

5.4.2 Reliability of the instrument used for data collection:

The questionnaire was formulated using inputs collected from literature review, experienced persons in the academia and industry experts. The questionnaire was split into 4 segments to check the reliability, viz, Energy Management processes, Energy efficient methods adopted, Challenges (Barriers) and motivational Forces (Drivers).

The reliability test used is Cronbach Alpha. The value above 0.7 for Cronbach alpha suggest the questionnaire is reliable and can be used for its design purpose. The results of the test are summarised in table 2

Segments	**Cronbach Alpha**	**Interpretation**
Current energy management policies and processes	0.873	This construct is measured by mapping relevant questions, and the value of 0.873 mean the measure is reliable.
Current energy efficient methods adopted	0.738	This construct is measured by mapping relevant questions, and the value of 0.738 mean the measure is reliable.
Drivers	0.775	The measured drivers have good internal consistency, as determined by a Cronbach's alpha of 0.775
Barriers	0.726	The measured barriers have satisfactory internal consistency, as determined by a Cronbach's alpha of 0.726

Table 2: Summary of reliability test for questionnaire.

5.4.3 Hypothesis testing:

For testing the hypothesis formulated the responses were analyzed using IBM SPSS Statistics v 25 software for Pearson correlation and Linear regression. Pearson’s correlation is used to measure the strength and direction of correlation amongst the matrix columns and the columns with the matrix score. Multiple linear regression is used as it helps realize the variation in dependent variable as

explained by independent variable. The individual columns of matrix were also analyzed using simple linear regression, with the matrix score to establish that there exists statistically significant association.

Correlations analysis

Figure 8, shows that there exists positive strong correlation (as $r > 0.5$) as per guideline provided by Cohen (1988) amongst each columns of EMMM and of the columns to the EMMM score. The strong association also indicates that increase score of any factors (columns) can increase the score of matrix leading to more optimized solutions. The energy management policies and process is strongly associated with all other factors of the matrix, indicating that with strong management commitment and considering energy as strategic to business will have positive influence on energy awareness and motivation amongst employees, lead to audit of energy components thereby influence more efficient and conservation approaches. This strong correlation also helps in more investments for energy optimization by the top management.

Figure 9, shows that the correlation amongst each columns of EEMM is positive but low ($0.1 < r < 0.3$) to moderate ($0.3 < r < 0.5$). The moderate correlation of energy conservation methods adopted with energy monitoring and records is a sign that non maintenance of the energy consumption, generation and losses data will deviate the energy conservation push. The older the production technology or less maintained plants can lead to use of more energy conservation methods as indicated by low correlation between them. The interesting outcome of negative association between ESPP and ERD and TOM can be associated with the energy consumption, loss and distribution records if maintained the saving potential can be calculated and applied and vice versa. Similarly between ESPP and TOM, the new technology with energy efficient equipment or fair frequency of maintenance or good housekeeping can decrease the perception of energy saving potential.

Correlations							
		MC1 EMPP	MC2 EA	MC3 EMR	MC4 AM	MC5 EI	EMMM Score
MC1 EMPP	Pearson Correlation	1	.706**	.692**	.718**	.554**	.897**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	61	61	61	61	61	60
MC2 EA	Pearson Correlation	.706**	1	.707**	.494**	.638**	.849**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	61	61	61	61	61	60
MC3 EMR	Pearson Correlation	.692**	.707**	1	.461**	.456**	.799**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	61	61	61	61	61	60
MC4 AM	Pearson Correlation	.718**	.494**	.461**	1	.509**	.790**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	61	61	61	61	61	60
MC5 EI	Pearson Correlation	.554**	.638**	.456**	.509**	1	.770**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	61	61	61	61	61	60
EMMM Score	Pearson Correlation	.897**	.849**	.799**	.790**	.770**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	60	60	60	60	60	60

**. Correlation is significant at the 0.01 level (2-tailed).

Fig 8: Pearson Correlations for EMM Matrix

Correlations							
		EC1 ERD	EC2 POM	EC3 ECM	EC4 ELMIPP	EC5 ESPP	EEMM Score
EC1 ERD	Pearson Correlation	1	.280*	.467**	.319*	-.068	.689**
	Sig. (2-tailed)		.029	.000	.012	.602	.000
	N	61	61	61	61	61	60
EC2 POM	Pearson Correlation	.280*	1	.148	.101	-.177	.416**
	Sig. (2-tailed)	.029		.255	.441	.172	.001
	N	61	61	61	61	61	60
EC3 ECM	Pearson Correlation	.467**	.148	1	.386**	.162	.805**
	Sig. (2-tailed)	.000	.255		.002	.211	.000
	N	61	61	61	61	61	60
EC4 ELMIPP	Pearson Correlation	.319*	.101	.386**	1	.119	.634**
	Sig. (2-tailed)	.012	.441	.002		.361	.000
	N	61	61	61	61	61	60
EC5 ESPP	Pearson Correlation	-.068	-.177	.162	.119	1	.351**
	Sig. (2-tailed)	.602	.172	.211	.361		.006
	N	61	61	61	61	61	60
EEMM Score	Pearson Correlation	.689**	.416**	.805**	.634**	.351**	1
	Sig. (2-tailed)	.000	.001	.000	.000	.006	
	N	60	60	60	60	60	60

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Fig 9: Pearson Correlations for EEM Matrix

There exists a strong positive correlation of columns (factors) with matrix score except the last column of energy saving potential perception which portrays moderate but positive correlation.

The Pearson Correlations for the DV with the IVs is shown in Table 3. The strong correlations amongst the dependent variable and the independent variables, and amongst the IVs themselves comments positively on the dependence of DV on IVs.

Table 3: Pearson Correlations for DV and three IVs

	Avg DV Score	RB	EMMM Score	EEMM Score
Avg DV Score	1	0.393	0.901	0.839
RB	0.393	1	0.380	0.280
EMMM Score	0.901	0.380	1	0.652
EEMM Score	0.839	0.280	0.652	1

The lack of record maintenance and non-realization of revenue or non-revenue benefits like tax benefits, lower rates per unit, stakeholder's willingness to invest, subsidies, etc., may be attributed to moderate correlations between EOP and RNRB.

Regression analysis

The linear regression for individual columns of the **EMMM** is summarized in table 4. The results indicate statistically significant association between the matrix column and Matrix score, $p<0.05$. The prediction association of each individual column with the overall matrix output is given by equation:

EMMM score = $\alpha + \beta$(regressor)

Table 4: Linear Regression results for EMMM

Column	R^2	α	β	F	Sig (p < 0.05)
MC1 EMPP	0.81	2.26	3.53	239.53	.000
MC2 EA	0.72	2.74	4.05	149.67	.000
MC3 EMR	0.64	3.21	3.36	102.46	.000
MC4 AM	0.62	3.65	2.97	96.36	.000
MC5 EI	0.59	3.46	3.06	84.40	.000

The linear regression for individual columns of the **EEMM** is summarized in table 5. The results indicate statistically significant association between the matrix column and EEMM score, $p < 0.05$. The prediction association of each individual column with the overall matrix output is given by equation: EEMM score = $\alpha + \beta$(regressor)

Table 5: Linear Regression results for EEMM

Column	R^2	α	β	F	Sig ($p < 0.05$)
EC1 ERD	0.69	7.17	2.09	52.32	.000
EC2 PAM	0.42	7.97	1.46	12.15	.001
EC3 ECM	0.81	7.32	1.81	106.65	.000
EC4 ELMIP	0.63	7.40	2.18	39.02	.000
EC5 ESP	0.35	8.97	1.11	8.16	.006

The **multiple regression** to find the significant relationship between **independent variables** EEMM, EMMM, RNRB and **dependent variables** EOP of chemical process SMEs. The multiple regression model statistically significantly predicted EOP, $F = 226.23$, $p < .005$, adj. $R^2 = 0.920$. All three independent variables added statistically significantly to the prediction of dependent variable (EOP), $p < .05$.

Regression coefficients and standard errors can be found in Table 6 (below).

Table 6: Multiple Linear Regression results for EOP

Model	R^2	Adjusted R^2	Durbin Watson	F	Sig ($p < 0.05$)
1	0.924	0.92	2.039	226.23	0.000

Model	β	Collinearity Statistics	
		Tolerance	VIF
Constant	-0.762		
CEMPP	0.116	0.854	1.171
CEEMA	0.133	0.532	1.878
RB	0.133	0.573	1.744

The prediction association of EOP with the independent variables EMMM, EEMM and RNRB can be described by equation below:

$$EOP = -0.762 + 0.116\,(EMMM) + 0.133\,(EEMM) + 0.133\,(RB)$$

The P value of 0.000 (Table 6) means that the probability of obtaining observed results for the null hypothesis is very low, leading to rejection of the null hypothesis **Thus all three null hypotheses are rejected leading to acceptance of Alternate hypothesis (Fig 10).**

Null Hypothesis	Accepted / Rejected
H_{01}: There is no significant association between Current energy management policies and processes of chemical process SMEs and Energy optimizing potential (tapped and untapped) of chemical process SMEs	**Rejected**
H_{02}: There is no significant association between Current energy efficient methods adopted by chemical process SMEs and Energy optimizing potential (tapped and untapped) of chemical process SMEs	**Rejected**
H_{03}: There is no significant association between Realization of benefits resulting due to energy conservation approaches by chemical process SMEs and Energy optimizing potential (tapped and untapped) of chemical process SMEs	**Rejected**

Figure 10: Testing of Hypotheses based on statistical analysis

The Energy optimization potential (tapped and untapped) for chemical process SMEs from the respondent data is as shown in Figure 11. Only 10 respondents of 60 responses, showed moderate potential for energy conservation, due to various proactive measures taken by them for energy management practices and optimization. 50 respondents display high to highest potential for energy optimization.

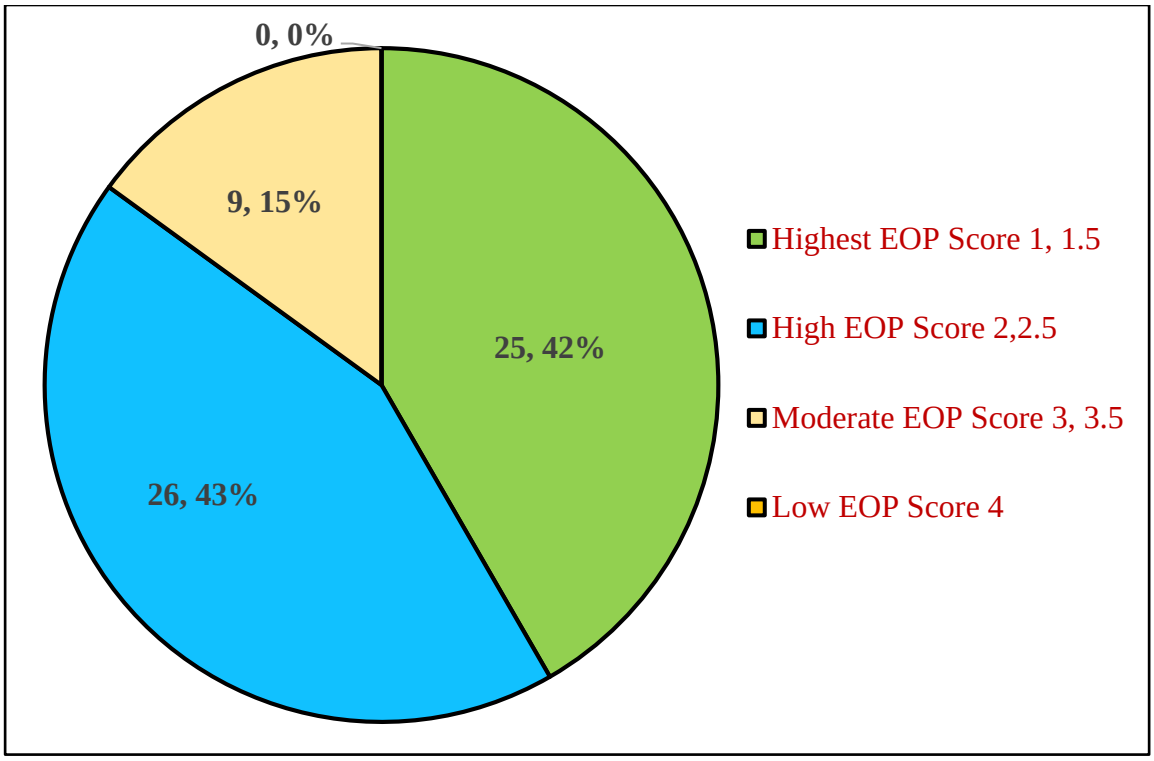

Fig 11: EOP analysis from the data.

Matrix score Analysis & Discussion

The mean for all data for individual columns of both matrices are plotted to understand the trend for chemical process SMEs from the data collected as in Figure 12, and Figure 13. The trend is more tilted towards energy efficiency; indication at least low cost measures are taken by majority of the responding firms. The low trend in the EMMM shows that the commitment from top management of the company can be very influential for overall development of energy management practices in the company. By continuously monitoring energy use, planning for energy resources, and ensuring that energy is always available for production operations at the best possible price, committed top management contributes to the reduction of process and utility wastes. The committed management will also win the trust of the company's stakeholders and be able to attract more investment. Top management of the company is also responsible for increasing awareness about benefits of energy conservation measures by training and employee awareness programs, for continued efforts towards their determined goals. Aware employees are an asset to organization, as they are self-motivated, and would ensure that energy optimization gets interwoven with their day to day activities. Energy audits can suggest many measures low cost or low pay back period that can lead to energy optimization.

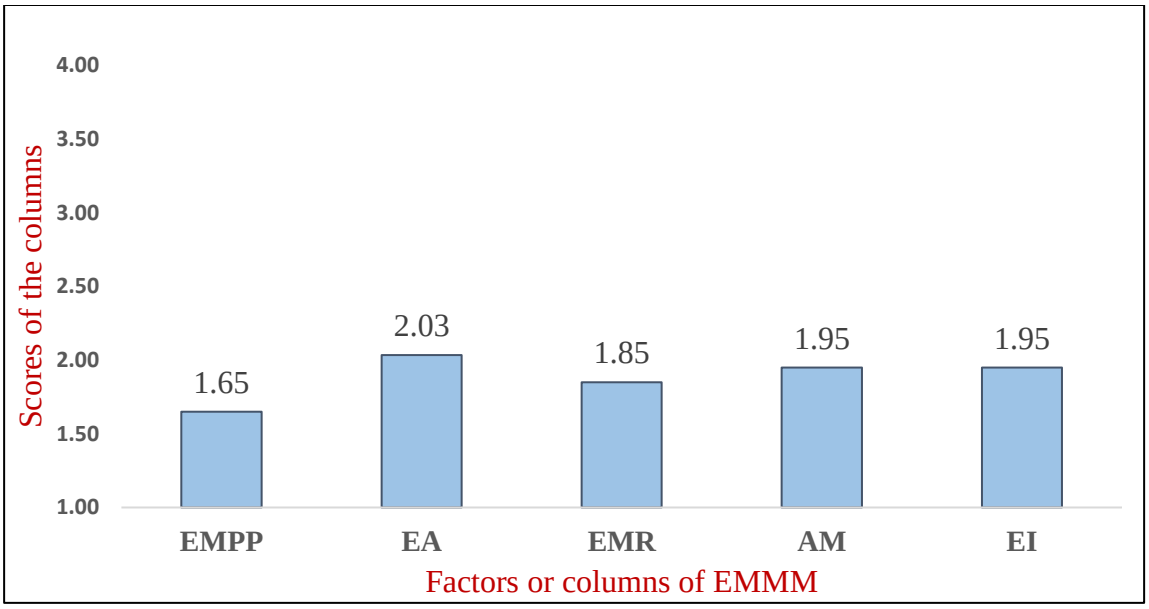

Fig 12: Column wise mean data for EMMM

Operations like regular maintenance of equipment or companies with new equipment or machineries have more saving in energy as compare to others due to advancement of technology. The perception of existing energy saving potential in the company also creates positive driving force to adopt energy conservation measures. The EEMM matrix's lowest score is in perception of energy loss occurring or even measurement of energy loss indicators. When firms resist from measuring the loss indicators like stack gas temperature, air – fuel ratio in boiler or furnace, power factor, etc., they remain unaware about losses occurring which results in more cost of production. There exists a decent gap between perception of energy saving potential and actual energy conservation methods adopted. It can be contributed to factors like investment requirement, payback periods, companies financial condition, availability of technology and finance, interest and awareness of the energy optimizing methods. The most essential outcome from the study is the fact that some SMEs still struggle to maintain the records of energy purchased, utilized, generated if any, and losses occurring. They deal on energy matters based on bills and process requirement.

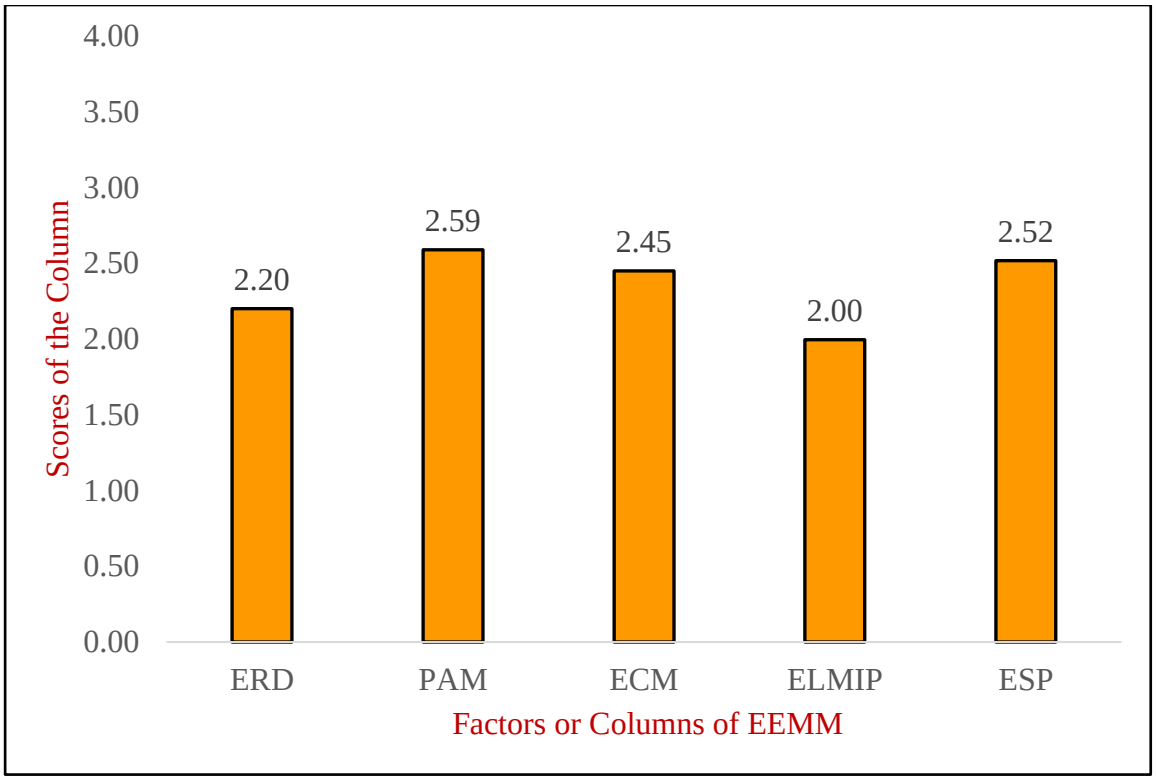

Fig 13: Column wise mean data for EEMM

5.4.4 Analysis of Influencing factors (Drivers) and Challenges (Barriers)

Since the study is exploratory, the investigation of practical barriers and drivers from literature review and survey both, for the adoption of energy optimization technologies and measures was decided by categorizing them as External factors and internal factors. The external factors are barriers and drivers expressed as the factors beyond the control of an organization. Some of these factors can be interdependent but in depth understanding of them is imperative for the successful implementation of energy management practices. The barriers and drivers that relate to the organization's role or are within the control of the organization are termed here as internal factors. The internal factors can be manipulated and controlled by the organization for its business performance. Organizations need to determine the internal and external factors as well as opportunities that are relevant to their business and can influence its ability to accomplish the energy management practices. This indicates that the organization has an understanding of the influences that positively or negatively stimulates their

energy management practices. The orange color bars in graphs below are external drivers and barriers whereas the blue bars are internal drivers and barriers (Figure 14 and 15).

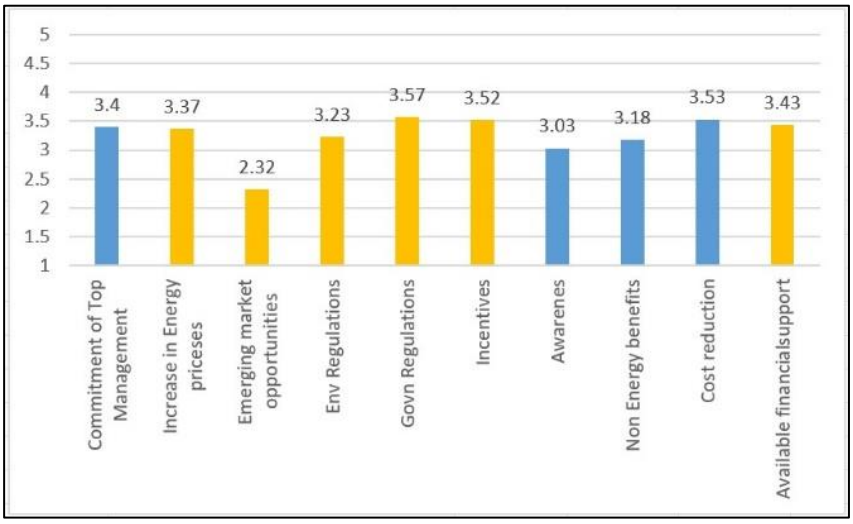

Fig 14: Drivers to Energy management practices

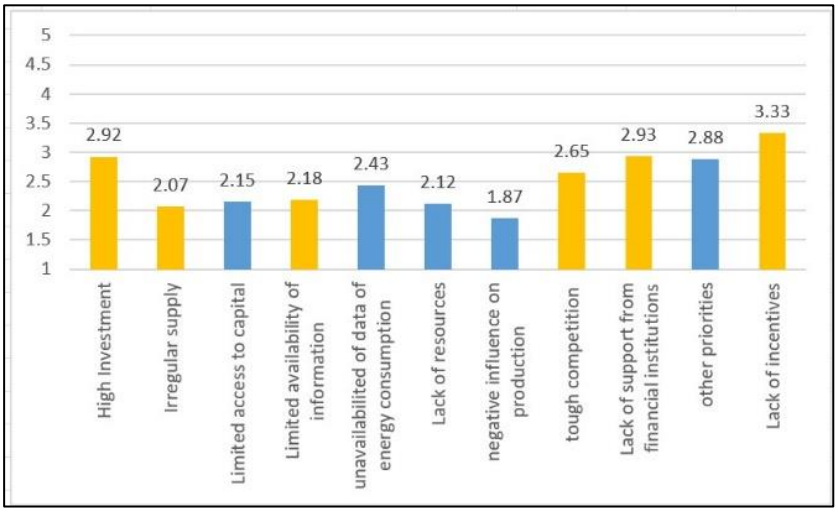

Fig 15: Barriers to Energy Optimization

Energy optimization can lead to cost reduction to overall process, is considered as top internal driving force, the realization of the same can promote adoption of energy conservation methods, followed by strong commitment of top management or proprietor of the business as evident from figure 11. Government regulations and rules ply more decisive role in managing the energy optimization, policies like mandatory energy audit, penalty on non-maintenance of power factor above 0.9, low

tariff rates for non-peak hour operations, etc., lead to more discipline related to energy conservation or management amongst the companies. Incentives in form of discounts for energy efficient equipments or machinery or financial support e.g. for energy audit, are also rated for high impact by the respondents for energy conservation approached.

Lack of incentives and perception of high investment for energy conservation approaches are considered more important external barriers, where as other priority, like more focus on production due to various factors is rated high for internal barriers. The non – availability of energy consumption, generation data, losses occurring, is playing major role in lack of awareness amongst some companies which was also evident from the response in the energy efficiency maturity matrix score (Figure 12). The busy schedules of the employees and need to manage the production within the tight budget specially for SMEs can also be considered as important challenge for adoption of energy efficient systems.

The external factors were studied using PESTLE analysis (Table 7), to enable their correct understanding and apply the focus accordingly.

Political factors

The organization's energy management policy and extent of use of energy-efficient technologies depend largely on the political disposition of the government. In India, the amendments to the pre-existing policies, framing of new policies to ensure the adoption of energy-efficient measures by industries is significantly visible, but its communication to the SMEs is acting as a barrier in recent times. For SMEs to undertake energy optimization and follow energy management practices, the central and state energy policies must be favorable and well communicated. Gujarat and Maharashtra fall in the category of contender which means, the states have a good scope of improvement and need to perform to achieve their full potential. The central and state government regulations and rules may motivate or demotivate the companies from adopting energy management practices, as reported as highest in the survey respondents.

Economic factors

The availability of energy at low price has potential to become barrier to adoption of energy-efficient measures as it does not provide incentive for companies.

Table 7: PESTLE analysis for External influencing factors from literature as well as survey.

PESTEL Analysis	Drivers from Survey	Barriers from Survey
Political	✓ Government Policy and regulations ✓ Incentives ✓ Success Stories	✓ Irregular supply of energy ✓ Lack of incentives
Economic	✓ Increases in energy prices ✓ Available financial support / loans	✓ Lack of support from financial institutions ✓ Higher investment for energy efficient technologies
Social	✓ Emerging market opportunities ✓ Competition	✓ Consumer /Supply Chain Demand ✓ Competition
Technological	✓ ESCOs / Access to expert	✓ Availability of energy efficient technologies ✓ Limited availability of public information
Environmental	✓ Environment Regulations	✓ Lack of stringent environment norms and Regulations
Legal	✓ Binding legislation or Regulatory control	✓ Lack of regulatory or binding legislation.

Cagno and Trianni (2013) and Minciuc et al., (2017) considers financial assistance, willingness and awareness of banks and other financial institutions to sanction the loan or financially help the companies for their energy-efficiency processes. This assistance works as biggest motivator, as evident from survey figure . The outsourcing compensation to energy consultants and experts may be the deterring factor for the companies willing to optimise energy use. Considerable respondents

gave high impact rating to the fact that energy optimization measures require moderate to high investment and the uncertainty on the payback period is a major concern.

Social factors

SMEs operates in highly competitive environment and their prime focus is production and balancing the forces of production, in this run, energy management and efficiency hardly finds any priority (Mittal et al., 2016). The additional investment on energy management practices is perceived as reduction in productivity. This barrier can be confronted by following proper energy management practices, thereby reducing the cost of production by reaping benefits of low energy consumption and bills.

Technological factors

Chemical process industry is generally considered as capital and energy intensive industry, therefore price for process or technology is the bargaining factor. The energy efficient technology, measures or process is available as patented/trademarked technology or at high price can become a deterring factor for firms to opt for it. High investment for energy efficient technology is discussed as barriers by the survey respondents. The irregular supply of energy is considered driving force, forcing the firms to conserve and optimise energy by application of relevant technologies is discussed in literature as observed by Parekh et al., (2019). Small disruption or fluctuation of power leads to decrease in power factor due to sudden shutdown and reopening of the heavy equipments (pumps, compressors, filters, centrifuges, etc), resulting in increased bills, as noted during the survey in Maharashtra.

Legal factors

The presence of regulatory or legally binding legislation, provision of standards and processes for comparison and benchmarking, rules regarding allocation, metering, billing, and reconciliation methods would be ideal influencer for firms to ensure energy efficiency at their premises. The lack of these factors gives industries an escape route from investing in energy efficient solutions. The discussions during survey reveals, that legal bindings and enforcement by government compels the otherwise busy firms to look into their energy consumption and conservation methods. The

association of industries in one of the dye and pigment cluster in Gujarat, enforces the emission standards, forcing the member companies to entrap the energy from waste gases and solids.

Environmental Factors

The survey brings to light the fact that strict environment regulations will ensure organization use appropriate methods and measures to reduce emissions and avoid pollution of water, air or soil. This directly implies that energy from waste needs to be trapped and use of alternate fuel to be preferred. The participated firms revealed their desire to shift to biofuels or clean energy options and many of them have actually shifted their operations to cleaner fuel. The regulations framed to protect environment, is adding to drive energy conservation and low carbon emission.

The internal factors were analyzed using SWOT method (Table 8) for identification of opportunities and threats that the companies face with respect to energy management practices.

Table 8: SWOT analysis of the internal factors from literature and survey.

STRENGTH	**OPPORTUNITIES**
• Organization Policy, Long Term Strategy • Commitment from Top Management • Realisation of non-energy benefits • Cost reduction due to low energy use	• Profitability • Increased employee awareness • Investments in R&D for energy efficient technologies / methods • Stakeholders willingness to invest
WEAKNESS	**THREAT**
• Limited access to capital by company • Limited clarity of energy consumption in the company • Limited knowledge of energy efficiency measures • Lack of resource (personnel and time) and skills for energy efficiency measures • Apprehension about potential negative influence on production performance • Lack of awareness / motivation amongst staff	• Increased Energy bills • Energy wastage • Opportunity loss of alternate revenue generation

Technical expertise, strategic agenda, behavioral factors and economic consideration of process industry builds internal factors of the organization. The strengths are the internal drivers or motivators that stimulates encashing of any available prospect to optimize energy. The challenges or barrier internal to organization weaken the prospects of actualizing energy efficient measures and are considered as weakness. The benefits tangible and intangible, revenue based or non-revenue based are the opportunities awaiting to be availed. The opportunity loss, business disruptions, higher payments for energy usage are considered as threats to the organization having negative impact on business.

Internal Strength and Opportunities

Energy management practices and energy efficiency methods when features on the long term strategy of company and organization policy means that, the energy is considered as CORE to business (Rudberg et al., 2013). Thus the company would use incremental techniques to ensure optimum energy use and conservation of energy. This would help in increasing profitability of company by reducing cost of production. Many of the survey respondents are of opinion, that the committed top management helps in reducing the process and utility wastes by continuously monitoring the energy utilization, planning of energy resources, and uninterrupted availability of energy for production operations and at optimal costs. Table lists the opportunities that can be fulfilled if the strength of the organization is utilized in a fruitful way. The committed management will also secure stakeholders trust and would be able to generate more investment for company. Respondents as well as literature review simultaneously points that realization of benefits will motivate employees. Energy efficient measures give opportunity to reduce cost of production, and increase profits. Switching to biofuel and use of energy efficient lightings, by few of the responding firms, have helped some respondents to reduce pollution and achieve considerable cost savings. Though the respondents consider cost savings achieved as driving force, many firms did not measure this benefit and were contend at the fact that they have employed some energy conservation approach.

Internal Weakness and Threat

For process industry to be sustainable, continuous monitoring of resources is essential. The internal factors deterring firms from adopting energy efficient measures are, limited clarity of energy consumption by the company and other priorities. This shows that the company is not considering energy as core resource and there is no track of energy consumption. The survey found that few firms

were reluctant to share data of their energy consumption as they do not maintain it at first place. Respondents (Figure) give moderate to high rating to unavailability of energy consumption data, this fact matches the SEEI's 2019 report, about lack of data. This can lead to 'threats' in the form of energy wastage and increased energy bills. The energy wastage may occur in form of energy loss from equipment/s or improper insulation, improperly designed piping network and lack of recovery from low thermal streams. This weakness can be tackled by continuous monitoring of energy consumption, energy losses and maintaining database.

5.4.5 Analysis of ECM adopted

Figure 16, represents the efforts put by the responding firms to reduce their energy consumption and achieve cost savings. 21 firms have adopted low cost measures like shifting their existing lightings to energy efficient lights, 17 respondents have opted for measures with low payback time, like waste heat entrapping, or use of automated switches or generation of solar power to an extent. 12 respondents are yet to begin their energy optimization journey. Few companies have proactively replaced their moving drives with variable speed drives (VSD) wherever possible, or have opted for replacement of fuel, or shifting to energy efficient equipment, enabling them to have substantial savings in the energy used by them. The respondents revealed that they used external energy experts or energy audit recommendation to recover heat energy as opportunity.

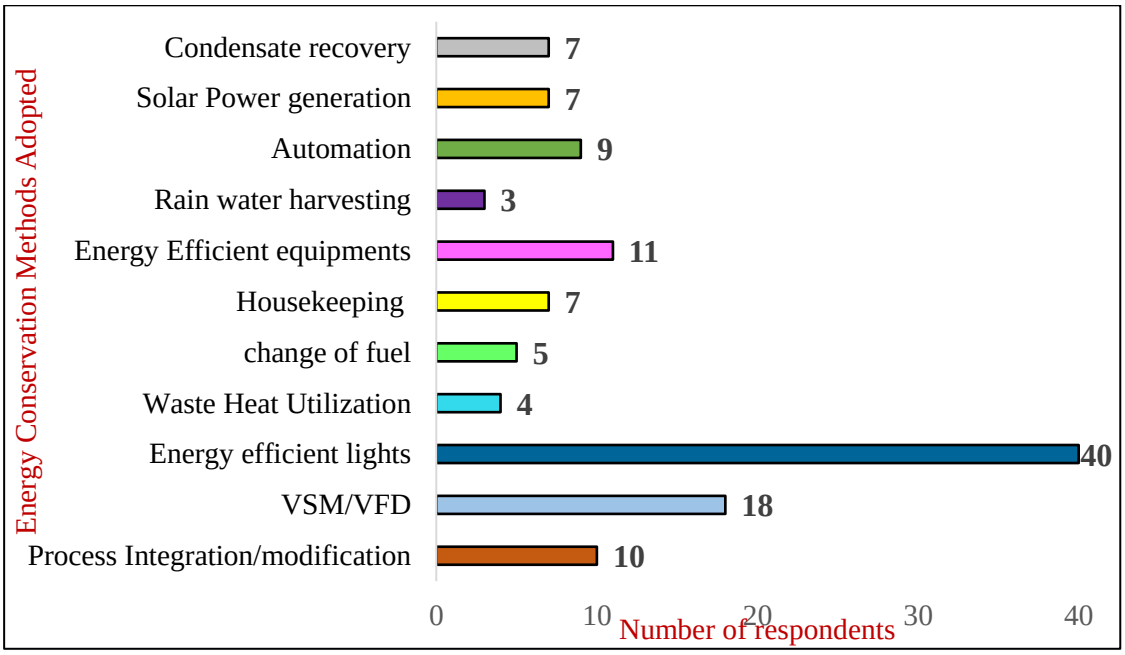

Fig 16: Energy conservation methods adopted by the companies

CHAPTER 6

CONCLUSION

6.1 Summary of findings

Energy optimization is the pressing need to mitigate the impact of energy use on climate change on a macro scale. The extensive use of fossil fuels in industrial operations, rising fuel prices, and its fluctuating availability is driving the global movement to conserve energy, increase energy efficiency, and manage operations with minimal energy resources. The research focuses on requirements and ways to improving energy efficiency, the means to conserving energy, and the importance of managing these within organizations. It also focuses on the barriers to and drivers of energy management practices in industry. Essentially three gaps were identified from the literature and primary data collected by personal visit to plants and structure questionnaire. These gaps are: 1) a lack of integration of management and technology perspectives, 2) lack of policy intervention and implementation, and 3) failure by organizations to consider energy as a strategic objective on par with productivity. The aim of the research is to understand how the chemical process SMEs are currently placed in terms of using energy management practices and to identify the existence of the potential for energy optimization in light of the government policies and the environment in which it operates.

To achieve the objectives of the research and answer the research questions, a theoretical framework is designed. Based on the framework, Energy management maturity matrix and Energy efficiency maturity matrix is designed. These matrixes can function as instrument to show path to achieve energy optimization. The matrix helped in prediction of dependent variable i.e. Energy optimization potential (tapped and untapped) for chemical process SMEs. The result obtained were statistically significant and null hypothesis is rejected. The regression analysis showed that the independent variables were statistically associate with the dependent variable, and there exists correlation between the variable as evident from Pearson's correlation analysis.

The research also reveals that the integration of technology and management approaches to energy optimization is still in nascent stage. Such an integrated approach may be termed a "techno managerial approach" which combines the benefits of managerial and technological perspectives,

detailed analysis of positive and negative influencing factors, and the local and national energy policies; such an approach would serve as a useful tool for industry.

This research identifies a gap in the studies related to energy management policy implementation in various industrial sectors across different locations. Energy efficiency policies and initiatives devised by governments do exist, but research shows they are rarely implemented by industry.

6.2 Recommendations

Energy cost is normally second to raw material costs in the energy intensive chemical process industry, thereby making considerable attention on energy conservation and optimization there imperative. To effectively achieve this ambition, energy must be adopted as a strategic objective by business. The strategic importance of optimizing energy use percolates from top to bottom in an organization's management, necessitating responsibility and accountability for the wastage of energy resources. This also helps determine the non-energy benefits of energy-efficient systems and energy management practices, including possibility of generating alternate revenue (Rudberg et al., 2013, Parekh et al. 2022).

The monitoring of the cost reduction and other non-energy benefits should be mandatory to ensure that energy management and energy efficiency is a continuous improvement process. Realization of the non-energy benefits like opportunity of portraying the company as energy and environment friendly, increased stakeholders trust, investments for R & D for energy efficiency, and availing of government benefits (tax concessions, subsidies) can act as motivational forces.

Failure to realize non energy benefits, can lead to threat in terms of generating alternate revenue. With energy audit and energy manager in place, various alternative revenue generation options can be worked upon like electricity generation from surplus energy available in process industry, generating steam from waste heat and selling it as product to nearby companies. The non-energy benefits also include shareholder's willingness to invest, getting carbon credits and trading them and green image of company. All these could be opportunity loss if not encashed.

Trust on Energy service companies (ESCOs) and consultants will dependent on how the experts/consultants and ESCOs, handles and understands the problems of the company and how well

trained and experienced they are. Since SMEs operate in highly competitive arena, the responsibility to persuade and encourage them towards energy efficient systems lies on state energy agencies, ESCOs and independent energy consultants as revealed during discussions in the survey.

Ambitious energy efficiency improvement targets need to be set by governments with strategies for implementing them on the ground. The policy to penalize the companies achieving power factor less than 0.9 and incentivizing by giving discounts for power factor above 0.95, by both states, have encouraged many firms to at least measure and maintain the PF above 0.9. This in itself is a energy and cost saving. Awareness creation, training and workshops are need for SMEs to understand the importance of energy optimization and incorporating it strategically. Both the state governments give tax benefits for renewable generation, but this benefits are yet to be reaped as companies generating renewable energy also do not opt for the same due to added paper work.

The research concludes that there exists high potential for energy optimization in chemical process SMEs, even though some measures are being taken by the companies either proactively or under government pressure.

CHAPTER 7

FUTURE SCOPE

7.1 Scope

India wants to achieve the ambitious target of reducing carbon intensity of its economy by less than 45%, by 2030, low carbon scenario is the only option with enhanced energy efficiency from both the energy security perspective and the sustainability perspective. To achieve this, the government of India takes up on priority strong energy efficiency strategies across multiple sectors.

Post Covid 19, chemical and other manufacturing activities shifting from China to India, all the more reason to ensure energy optimized and sustainable production. Putting energy in business strategy will ensure sustainability of businesses.

The matrices developed can be extended to other sectors as well with minor modifications for process industries in others states of India to obtain more diverse perspective. Though the design is based on the operational features of chemical process industries, the measures are universal and with minor modifications can be applied to other industries, which consumes appreciable amount of energy as well as organization working towards reducing carbon footprint and wish to be sustainable, with industry appropriate modifications.

Thus, the future scope is enormous in the area of energy optimization, and realization of the revenue benefits of putting energy as strategic agenda, which will motivate the industries, academics and policy makers in the positive direction for future research.

The research on region wise and sector wise comparison can be considered in future to improve the competitiveness amongst the states and sectors.

7.2 Limitations

This study is exploratory and based on the data from 60 companies of the two states of India. The framework and matrices developed are yet to be tested by applying into the industries. Further research would increase the validity of the matrices and framework along with the conclusions of this study. The hesitancy of the firms to share their energy data have led to incomplete responses by some participants, which we had to remove while cleaning the data. Some firms refused to participate, as they do not monitor and measure their energy usage. The adequacy of the data may have some limitations due to the sectors' unwillingness to share the information.

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